2004 HYDROGEN, FUEL CELLS INFRASTRUCTURE TECHNOLOGIES PROGRAM REVIEW

FUEL CELL OPERATED SMART HOME

BY

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OBJECTIVES

- To demonstrate that a 5kW Fuel Cell Power Plant (FCPP) can satisfy the power demands of an all electric home.
- To demonstrate that the FCPP can handle both transient and steady-state conditions.

BUDGET

- Phase I: $2m
- Phase II: $1m

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TECHNICAL BARRIERS AND TARGETS

Lack of Demonstrations or Examples of Real World Use:

- The 'Fuel Cell Operated Smart Home' gives educators and students the opportunity to gain hands-on and personal experience to improve their understanding and comfort when using fuel cell technology.
- Currently there are only a few real-world examples to which educators can point. The absence of installations and demonstrations also results in a lack of success stories and case studies to supplement educational materials and encourage early adopters.

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APPROACH

- Laboratory home constructed and equipped with standard all electric appliances.
- A Smart Energy Management Control (SEMaC) system developed to reschedule loads.
- Commercially available Fuel Cell purchased
- Home uses a sensor suite (current, occupancy, temperature and humidity sensors).

SAFETY

- University of South Alabama Office of Research Compliance and Assurance inspects all laboratories annually.
- Fuel Cell has extensive safety interlocks.
- All electrical distribution panels have safety lockouts.

PROJECT TIMELINE

- Phase I: Laboratory House and SEMaC completed.
- Phase II: Micro-grid, LEMSYS and MEMSYS being developed.

TECHNICAL ACCOMPLISHMENTS/PROGRESS

- Load profiling and data collection.
- Fuel cell lab/house built.
- Fuel cell purchased and commissioned.
- Designed and developed SEMaC.
- Integrated system components.

INTERACTIONS AND COLLABORATIONS

- Teamed with Radiance Technologies, Inc. to develop SEMaC.
- Made contact with other fuel cell research groups including CRN, Houston Area Research Center (HARC), and the Fuel Cell Testing Center (FCTC) in Johnstown.

FUTURE WORK

- In Phase II, a single FCPP is being used to supply ten homes in a Micro-grid configuration.
- Each home is equipped with a Local Energy Management System (LEMSYS).
- A Micro-grid Energy Management System (MEMSYS) is being developed to coordinate the individual LEMSYS systems.
- Thermal recovery strategy.
- Economics and reliability of the micro-grid.

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FUTURE WORK (Contd.)

- Economics of the Macro-grid.
- Hydrogen cogeneration and storage.
- Power control at the appliance level.
- Peak load reduction strategies.

- The average household power consumption is usually substantially lower than the peak power consumption.
- Some high-current appliances account for the majority of the power usage in houses. Water heaters, ovens, stoves, and air conditioning are among the high-power appliances.
- In a typical home, each of the above appliances can use in excess of 5 kW of power.
- Use of several high-current appliances simultaneously can lead to a much more than average power demand.
- A smart energy management system that can reduce power consumption by shaving unnecessary power usage and by load scheduling can dramatically reduce the peak power demand.

HVAC, Water-heater, Iron, Dryer, and Range in use. For managed total load, **some devices that were to be turned on in certain homes have now been rescheduled to run throughout the day, making for a smaller peak.**

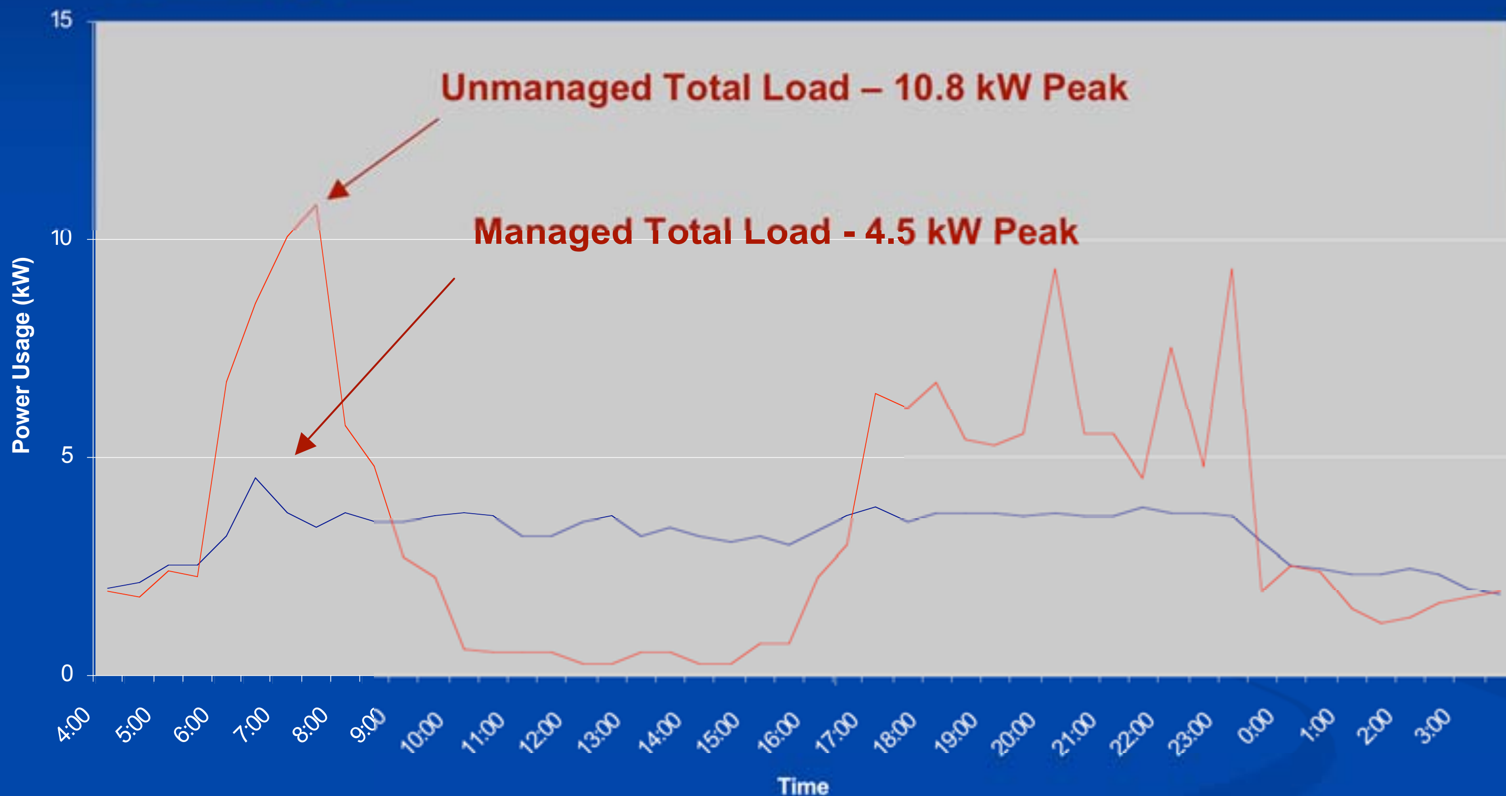


Figure 1 - Electric power usage in a typical house

The Model House

- To demonstrate that such a Smart Energy Management System can reduce the peak power demand and save energy at the same time, a two-room Model House has been built at the University of South Alabama.
- The model house is a two-room house, approximately 500 square feet area, and built inside a building at the University of South Alabama. The rooms are a living room and a kitchen. Figure 2 shows the layout of the model house.

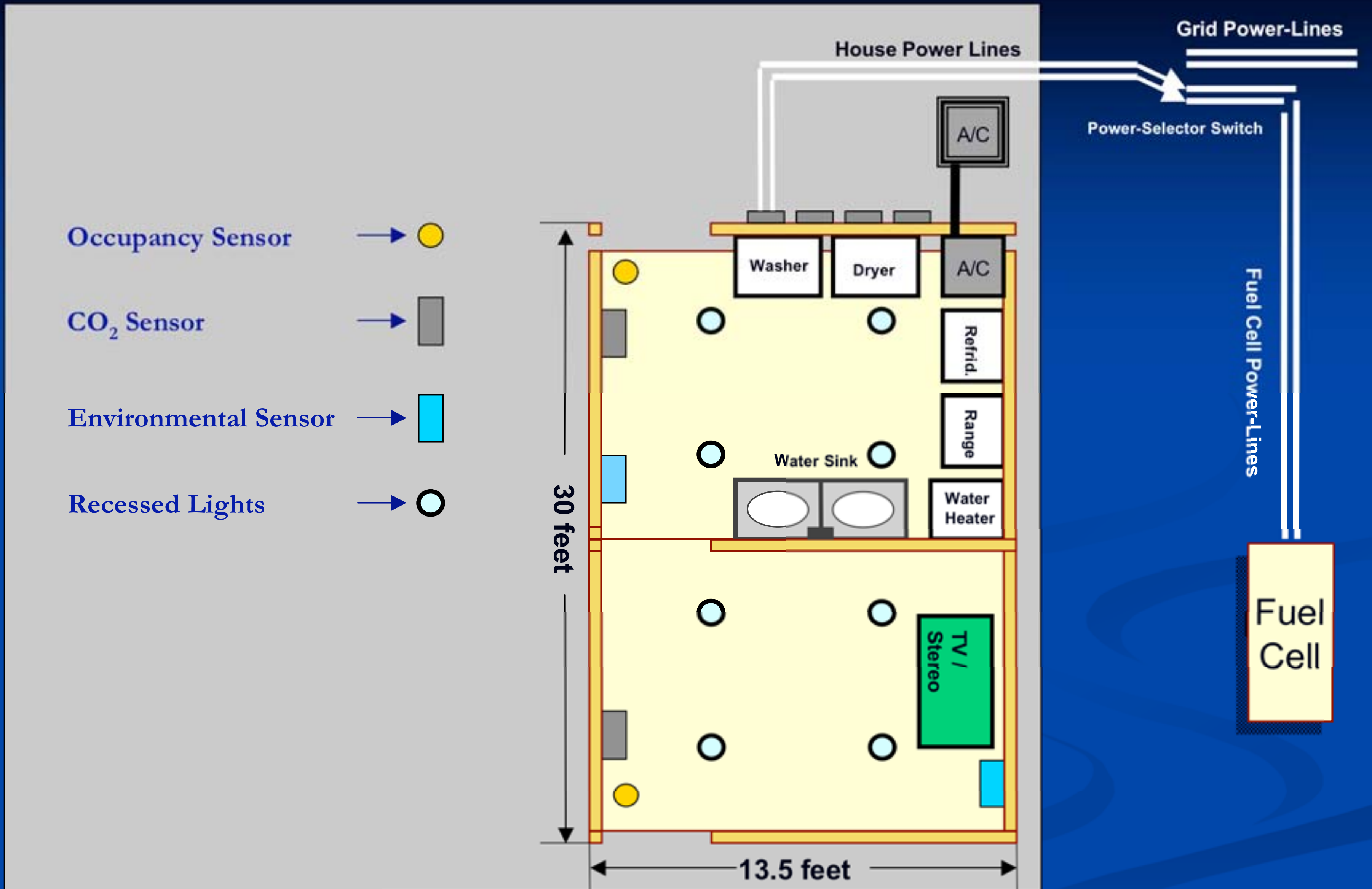


Figure 2 - The Smart Home Layout

Inside The Fuel Cell Operated Smart Home

- Common appliances, furniture, and other equipment found in a typical house were installed in the model house to make the simulation as close as possible to that of an actual house.

Appliances and Furniture Used In The Model House

Living Room

Television, entertainment center, furniture, iron, and a vacuum cleaner.

Kitchen

Refrigerator, range, electric washer, electric dryer, electric water heater, double sink, microwave, blender, toaster oven and dishes.

Also, ceiling fans, advanced occupancy sensors, temperature and humidity sensors, and appropriate air ducts were also installed in both rooms.

Data Collection in the Model House

- Current sensors to monitor power consumption in every circuit.
- Occupancy sensors.
- Temperature and humidity sensors for each room.
- CO_2 sensors to collect data for future generation of occupancy detection.

System Description

Two sets of hardware/software were used in the system:

- The Smart Energy Management and Control System (SEMaC)
- System Hardware Controller (SHC)

The Smart Energy Management and Control System (SEMaC)

SEMaC consists of the following components:

- High-speed host PC
- High-speed 12-bit A/D board
- Digital I/O board
- Analog multiplexer board
- Sensor suite (current, occupancy, environmental)
- Smart Energy Management and Control software residing inside the host PC

System Hardware Controller (SHC)

The following components make up the SHC:

- A Motorola ColdFire processor and its associated components
- A set of solid-state relays
- Embedded ColdFire processor code

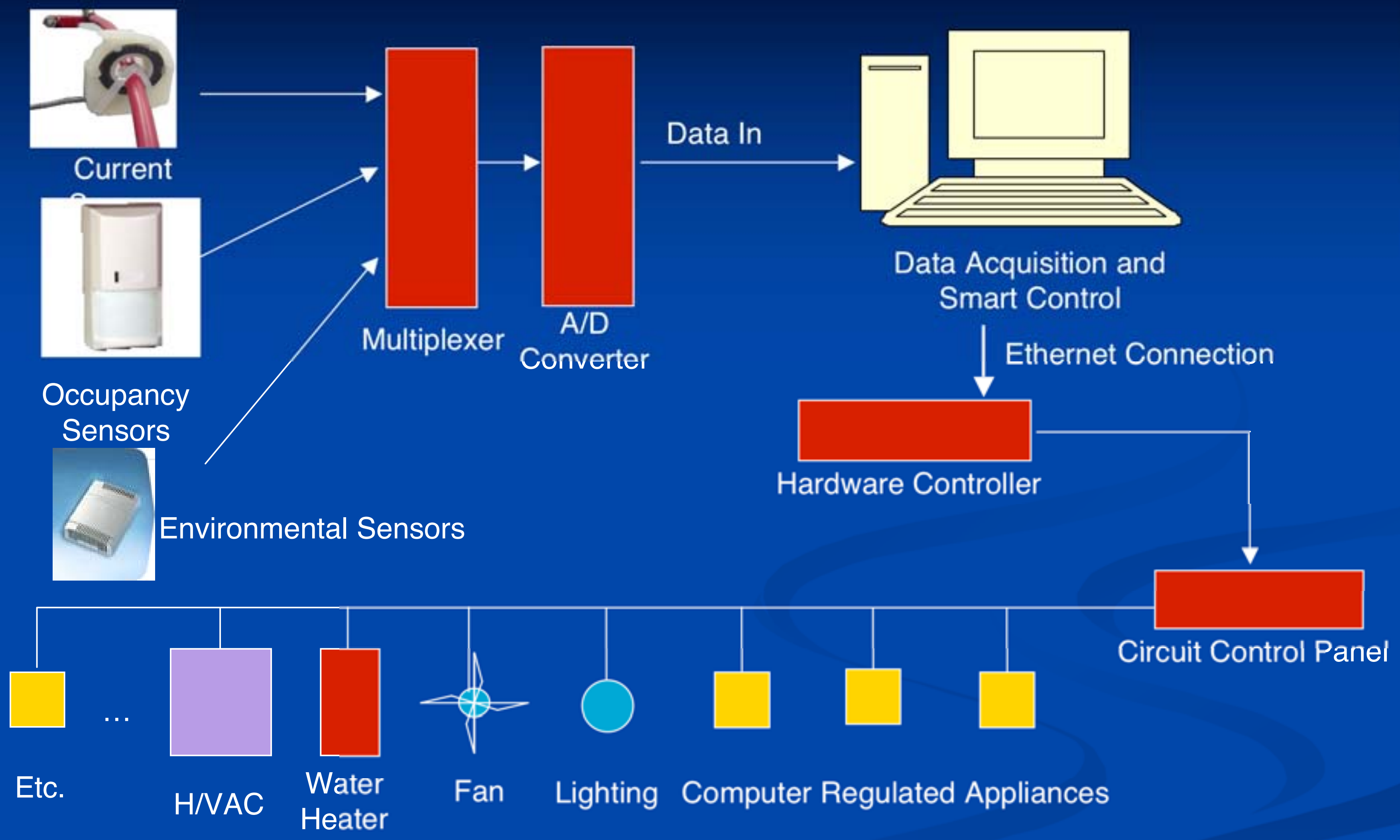


Figure 3 - SEMaC Control Layout

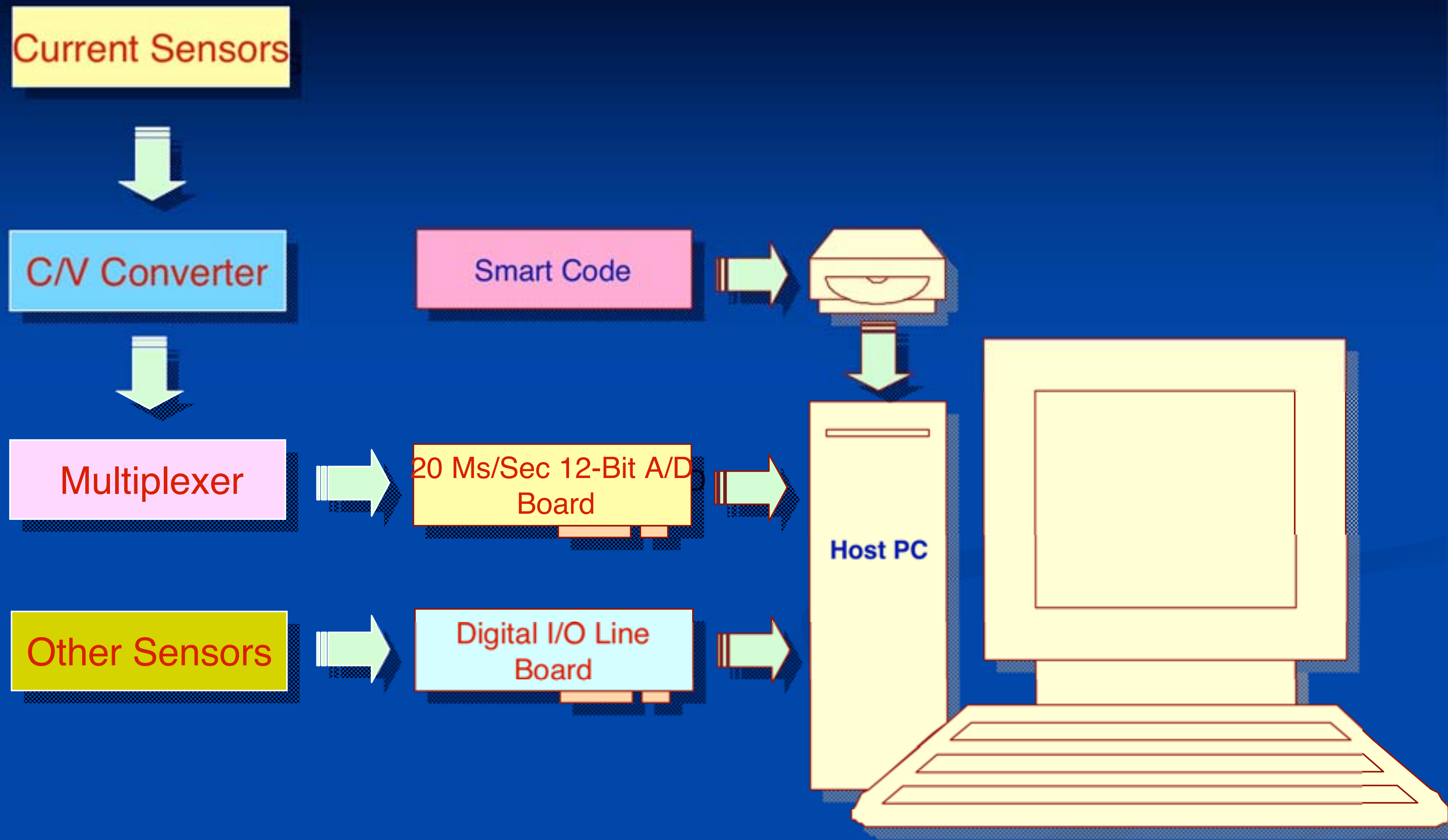


Figure 4 - SEMaC System Block Diagram

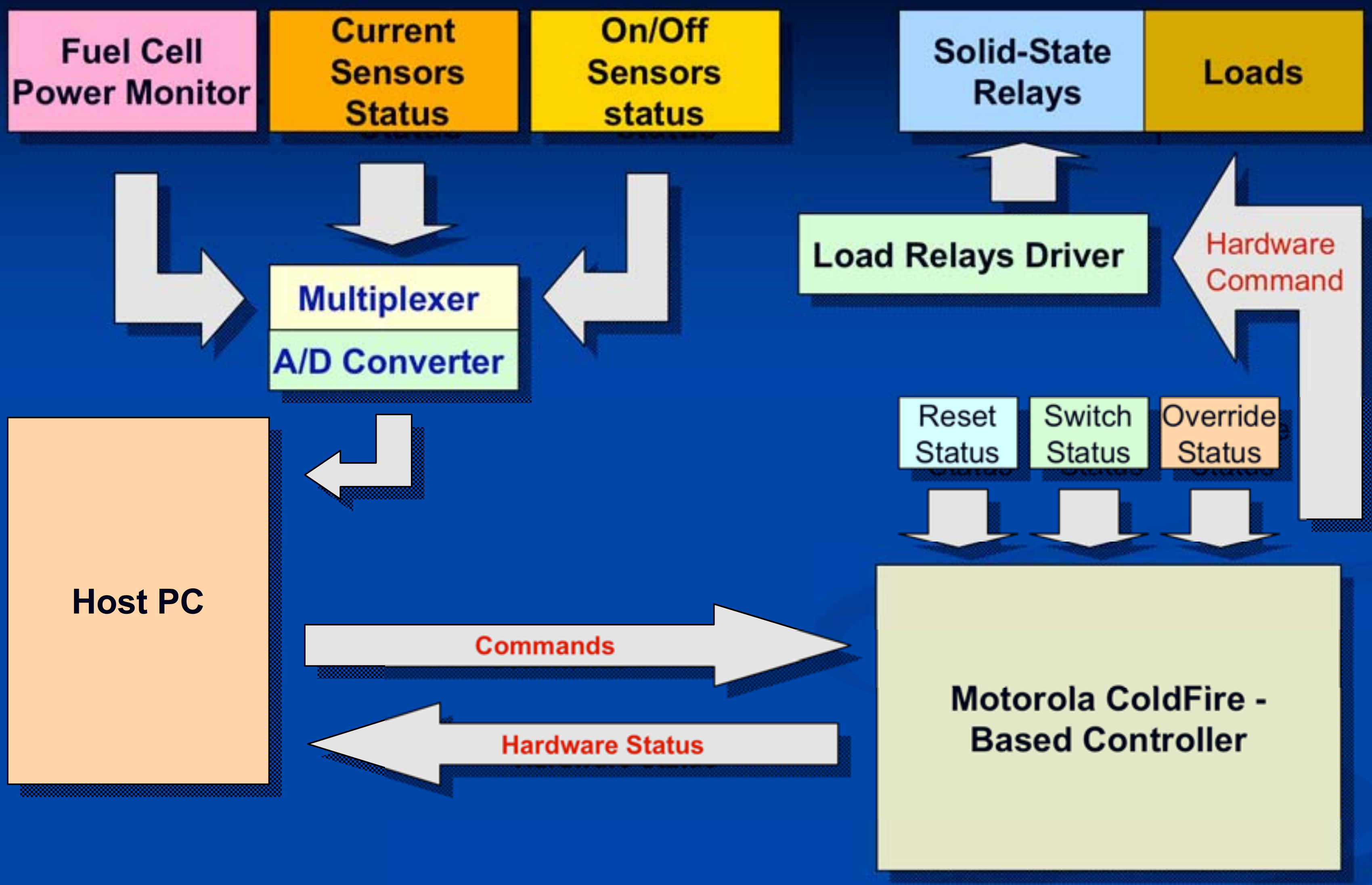


Figure 5 - Communication Between SEMaC and SHC

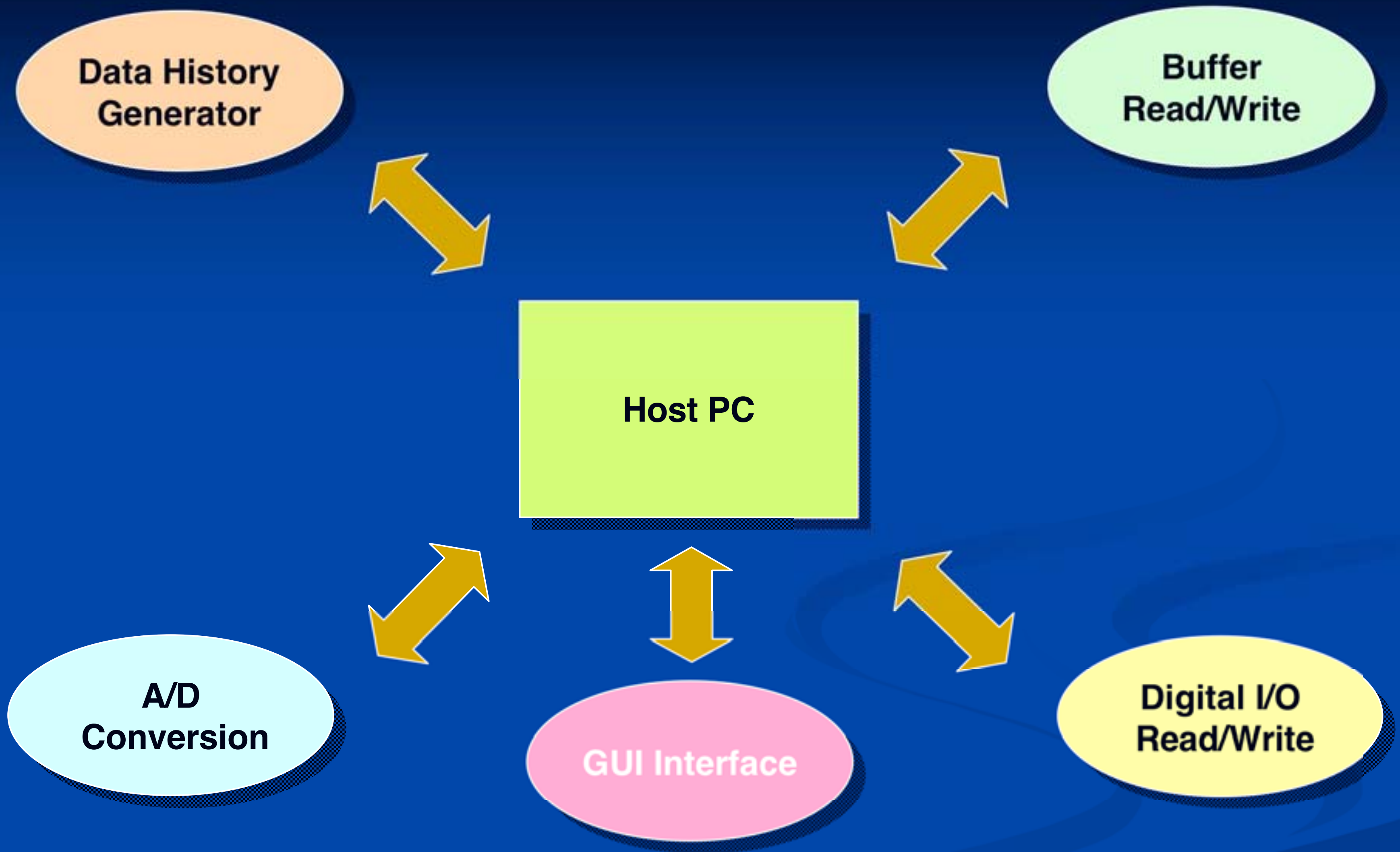


Figure 6 - Modular approach for the SEMaC architecture

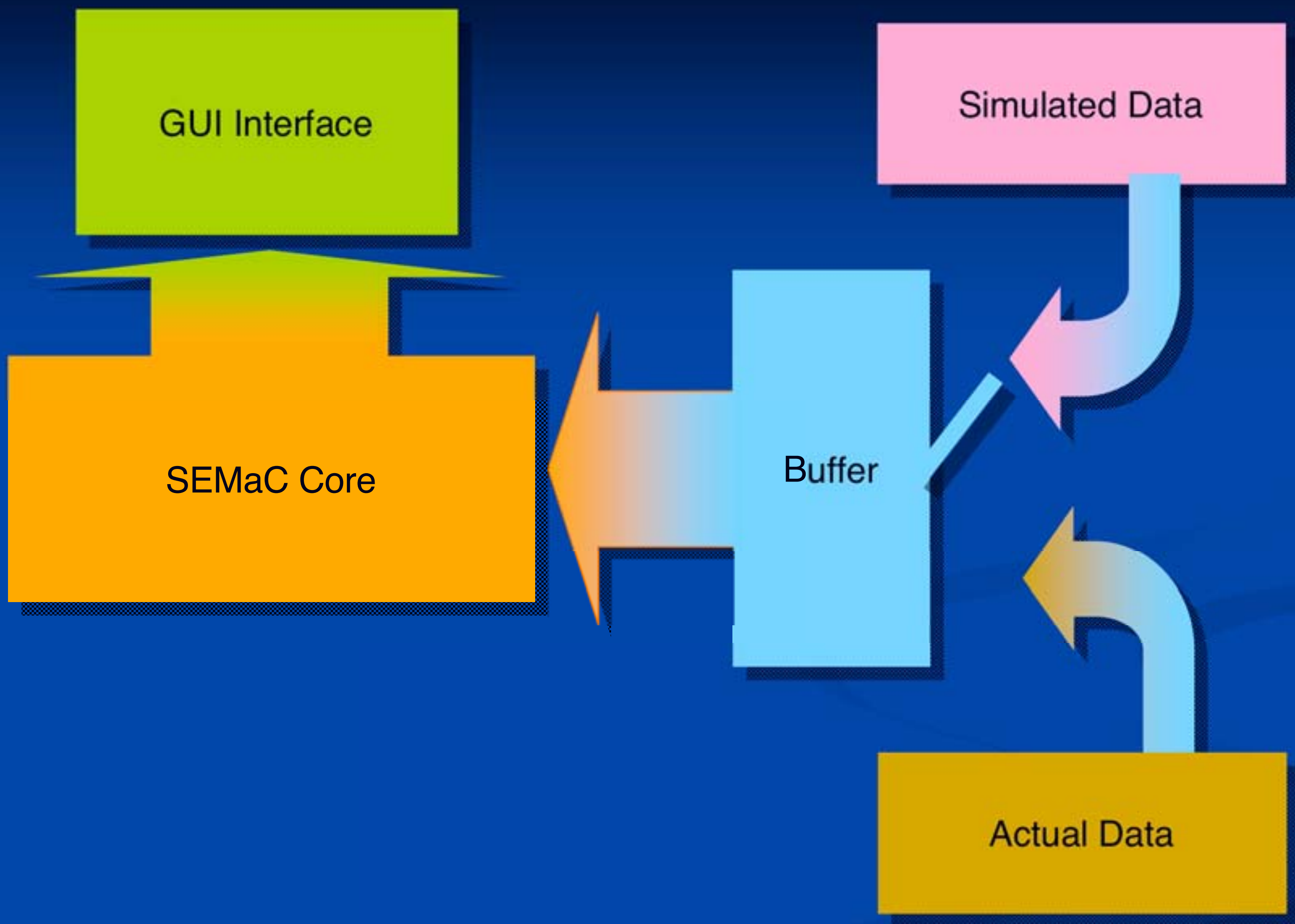


Figure 7 - SEMaC operation from both simulated or actual data

Typical SEMaC Sequence

1. Read device priorities.
2. Read power source specifications.
3. Read device override status.
4. Read load profile (from all sensors).
5. Add up power consumption and compare it with the total available power.
6. Perform energy management algorithm, and return to step 3.

SEMaC Load Management

Benefits:

- Performs load leveling.
- Reduces overall power consumption by turning off unneeded devices.
- Increases fuel cell reliability.

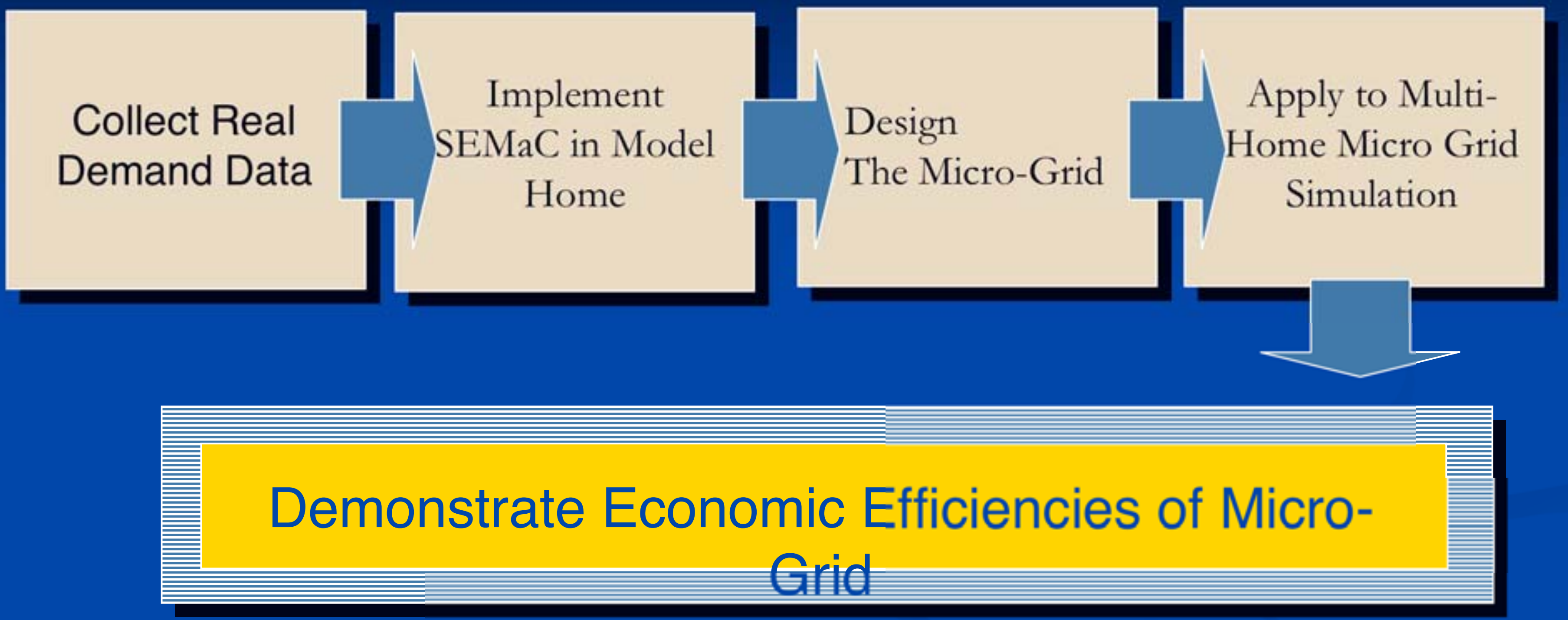
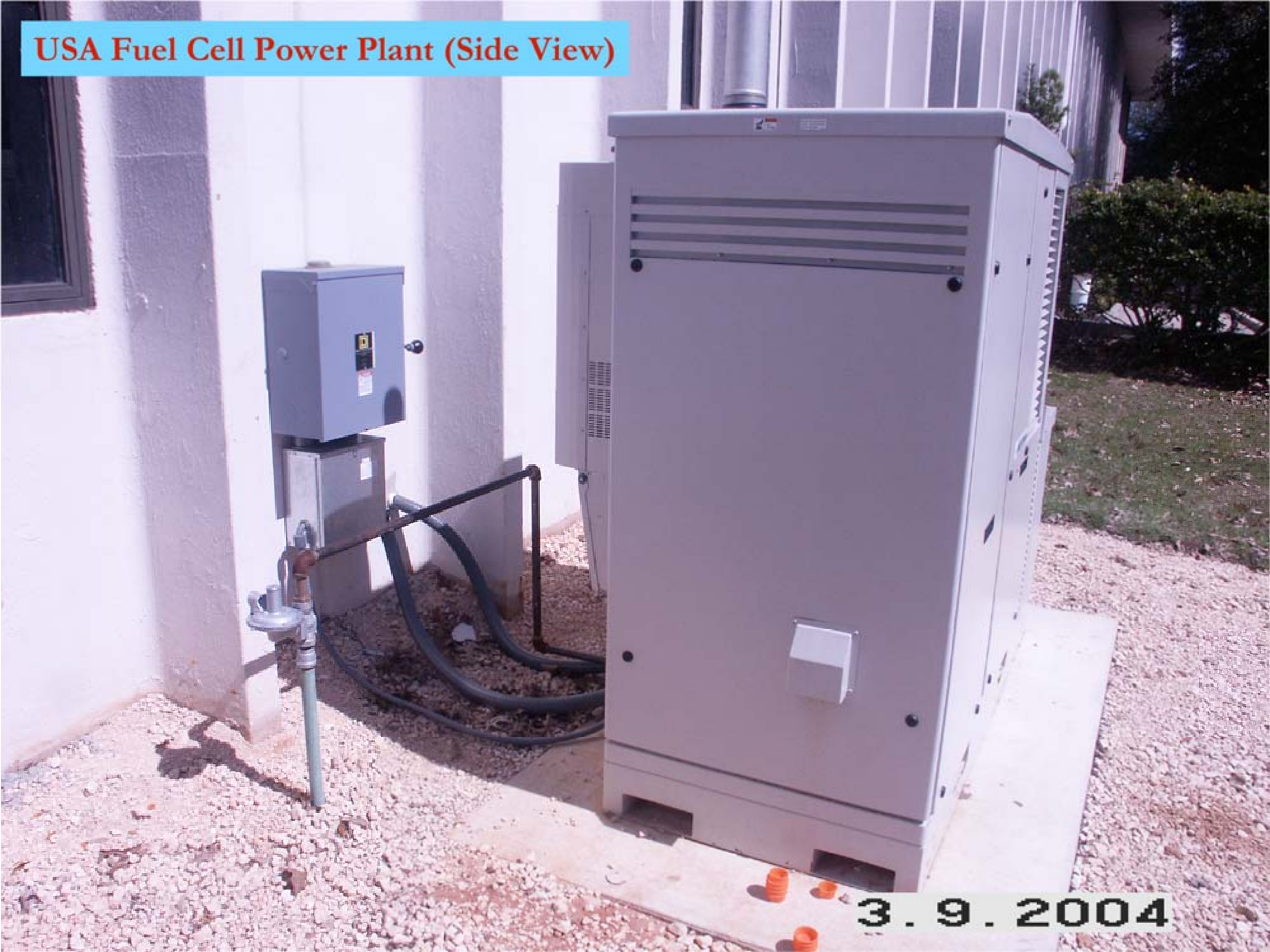


Figure 8 - Pathway to Micro-Grid Application

USA Fuel Cell Power Plant (Side View)

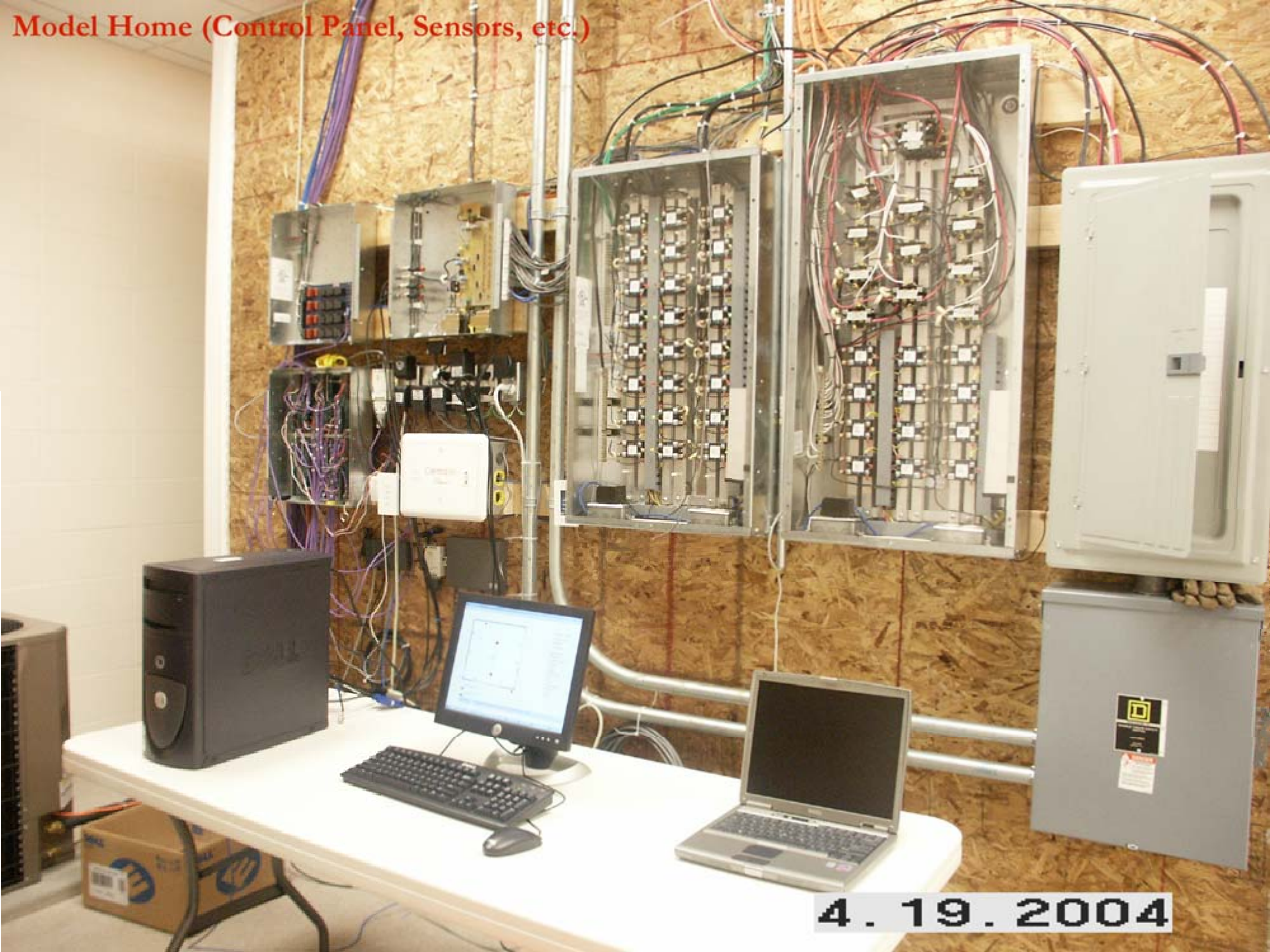


USA Fuel Cell Power Plant (Front View)

Inside the Model Home (Kitchen)

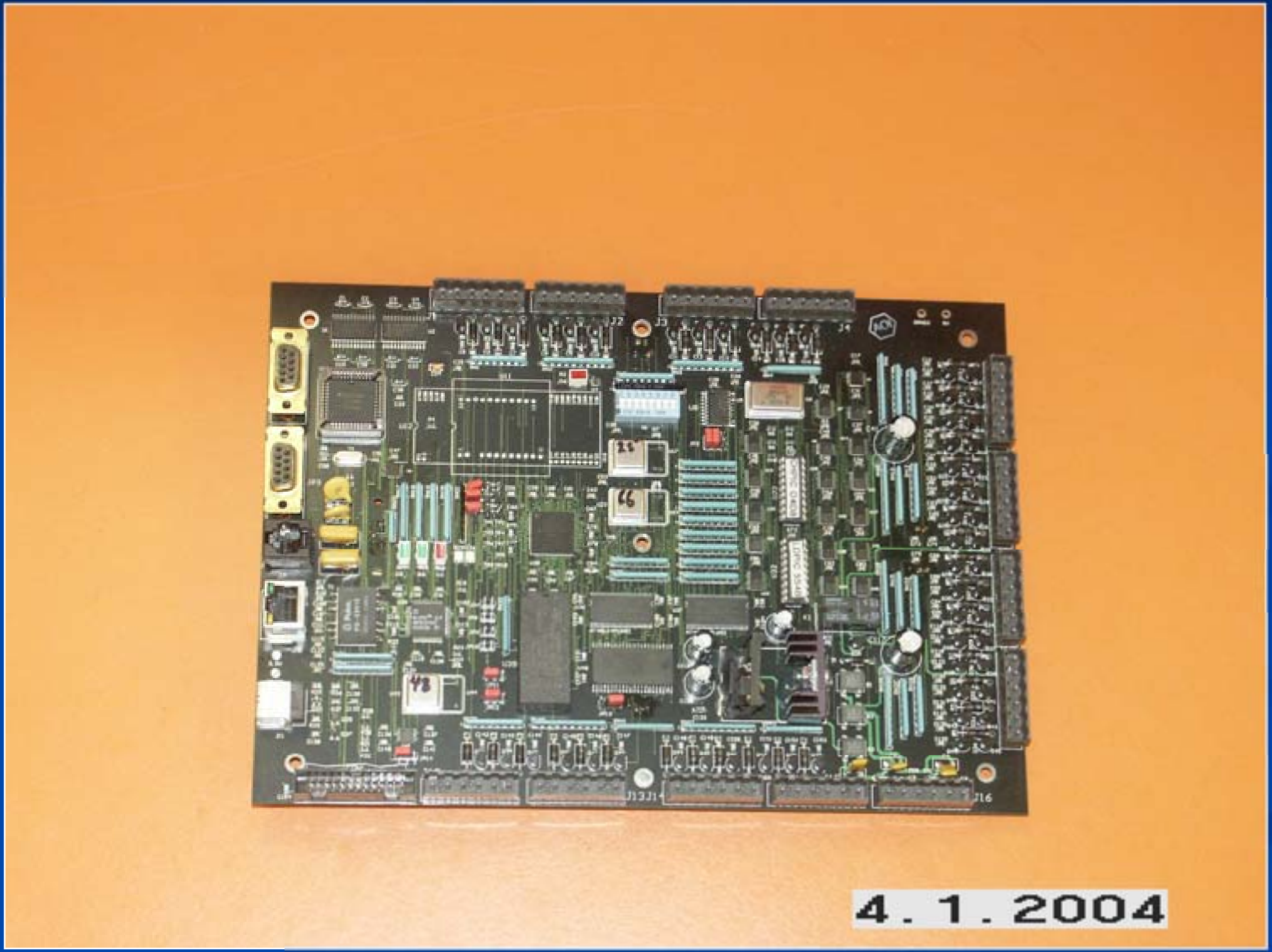
Inside the Model Home (Living Room)

Model Home (Control Panel, Sensors, etc.)



Outside View of the Model Home)

System Hardware Controller Board (Developed at USA)



Publications Resulting From This Project

- M. Y. El-Sharkh, A. Rahman, M. S. Alam, A. A. Sakla, P. C. Byrne and T. Thomas, "Analysis of Active and Reactive Power Control of a Stand-alone PEM Fuel Cell Power Plant," accepted for publication, *IEEE Transactions on Power Systems*, 2004.

- P. C. Byrne, A. Rahman, A. A. Sakla, M. S. Alam, T. G. Thomas, M. Y. El-shark and K. Avadhanam, "Proton Exchange Membrane (PEM) Fuel Cell Steady-State Model for Residential Use," under review, *Journal of Power Source*, October 2003.

- M. Y. El-Sharkh, A. Rahman, M. S. Alam, P. C. Byrne, A. A. Sakla, and T. Thomas, "Proton Exchange Membrane Fuel Cell Dynamic Model for Residential Use," under review, *IEEE Transactions on Energy Conversion*, August 2003.